# Strength Differential Measured in Inconel 718: Effects of Hydrostatic Pressure Studied

Aeropropulsion components, such as disks, blades, and shafts, are commonly subjected to multiaxial stress states at elevated temperatures. Experimental results from loadings as complex as those experienced in service are needed to help guide the development of accurate viscoplastic, multiaxial deformation models that can be used to improve the design of these components. During a recent study on multiaxial deformation (ref. 1) on a common aerospace material, Inconel 718, it was shown that the material in the aged state exhibits a strength differential effect (SDE), whereby the uniaxial compressive yield and subsequent flow behavior are significantly higher than those in uniaxial tension. Thus, this material cannot be described by a standard von Mises yield formulation. There have been other formulations postulated (ref. 2) that involve other combinations of the stress invariants, including the effect of hydrostatic stress. The question remained as to which invariants are necessary in the flow model. To capture the physical mechanisms occurring during deformation and reflect them in the plasticity formulation, researchers examined the flow of Inconel 718 under various amounts of hydrostatic stress to determine whether or not hydrostatic stress is needed in the formulation.

Under NASA Grant NCC3-464, monitored by the NASA Glenn Research Center, a series of tensile tests were conducted at Case Western Reserve University on aged (precipitation hardened) Inconel 718 at 650 °C and with superimposed hydrostatic pressure. Dogbone-shaped tensile specimens (3-mm-diameter gauge by 16-mm gauge length) and cylindrical compression specimens (3-mm-diameter gauge by 6-mm gauge length) were strain gauged and loaded in a high-pressure testing apparatus. Hydrostatic pressures were obtained with argon and ranged from 210 to 630 MPa. The aged Inconel 718 showed a pronounced difference in the tension and compression yield strength (i.e., an SDE), as previously observed. Also, there were no significant effects of hydrostatic pressure on either the tensile and compressive yield strength (see the graph) or on the magnitude of the SDE. This behavior is not consistent with the pressure-dependent theory of the SDE, which postulates that the SDE is associated with pressure-dependent and/or internal friction-dependent deformation associated with non-Schmid effects at the crystal level (refs. 3 and 4). Flow in Inconel 718 appears to be independent of hydrostatic pressure, suggesting that this invariant may be removed from the phenomenological constitutive model. As part of an ongoing effort to develop advanced constitutive models, Glenn's Life Prediction Branch coordinated this work with that of research on the multiaxial deformation behavior of Inconel 718 being conducted at Pennsylvania State University under NASA Grant NCC597.
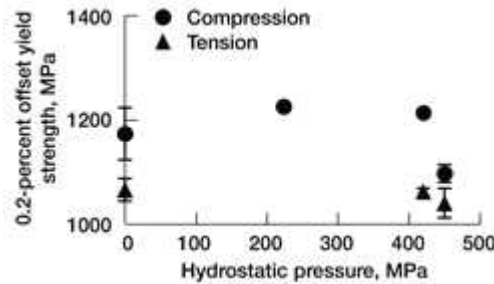
Tension (triangles) and compression (circles) yield strength as a function of hydrostatic pressure.

Long description of figure Graph of 0.2-percent offset yield strength versus the superimposed hydrostatic pressure for both tension and compression. The compression yield strength is approximately 1200 megapascals, and the tension yield strength is approximately 1050 megapascals. Both yield strengths are constant for pressures between atmospheric and 450 megapascals.

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References

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